**Table 2-4**
**GENERAL RESPONSE ACTIONS**
**FOR GROUNDWATER**
**With Initial Screening of Technologies and Process Options**

| General Response Action | Remedial Technology | Process Option | Description of Process Option | Technical Implementability/ Reason for Elimination |
|---|---|---|---|---|
| No Action | None | None | No action would be taken and operation of the existing water treatment plant (WTP) would cease. The contaminated area remains in its existing condition. | Required for consideration by NCP. |
| No Further Action | None | None | No new action would be taken, however the existing WTP would continue to operate without significant upgrades or repairs. | Retained for further consideration. |
| Institutional Controls | Land Use Controls | Deed/Zoning Restrictions | Restrict groundwater use through legally binding requirements on property such as deed and zoning restrictions. Restrictions would be used to prevent use or transfer of property without notification of limitations on the use of the property. | Retained for further consideration. |
| | Access Restrictions | Physical Restrictions (Posted Warnings and Well Security) | Warning signs would be posted to control access and onsite wells secured. Monitoring would be performed to ensure controls remain in place. | Retained for further consideration. |
| | Community Awareness | Information and Educational Programs | Community information and education programs would be undertaken to enhance awareness of potential hazards and remedies. | Retained for further consideration. |
| Monitoring | None | Long-term Groundwater Monitoring | Ongoing monitoring for COCs in groundwater. | Retained for further consideration. |
| | | Monitored Natural Attenuation | Contaminated groundwater would recover through natural in-situ processes such as dilution, biodegradation, adsorption, and chemical reactions with subsurface materials present in the aquifer. Site modeling would be done to demonstrate that contaminant concentrations would decline. | Retained for further consideration. |

# Table 2-4
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| General Response Action | Remedial Technology | Process Option | Description of Process Option | Technical Implementability/ Reason for Elimination |
|---|---|---|---|---|
| Containment | Hydraulic Barriers | Interceptor Trenches | Trenches would be installed across the groundwater flow path and water would be extracted to limit migration of the contaminants. | Technically feasible and potentially applicable in unconsolidated materials. Constructability concerns increase with depth. |
| | | Extraction Wells | Extraction wells would be pumped to create a capture zone for the groundwater and reduce further migration. | Technically feasible and potentially applicable. |
| | | Injection Well | Injecting clean water into the aquifer through injection wells would create a hydraulic barrier and alter groundwater flow direction to reduce off site migration of COCs. | Not Retained. Technically feasible but likely ineffective because of fractured bedrock and complicated hydrologic conditions. |
| | Physical Barriers | Slurry Walls | A subsurface slurry wall would be constructed as a barrier to block or reduce groundwater flow through contaminated material by excavating soil and bedrock and filling the excavation with a low permeability slurry. | Not Retained. Technically not feasible at this site because of constructability concerns with the depth to bedrock and lack of an aquitard to key into. |
| | | Grout Curtains | A subsurface vertical, low permeability barrier would be constructed as a barrier to block or reduce groundwater flow by injecting grout into the subsurface soil and bedrock through grout holes. | Not Retained. Technically not feasible at this site because of the complex 3-D flow system in the extremely heterogeneous fractured bedrock. In addition there are constructability concerns and no aquitard to key into. |
| | | Sheet Pile Walls | A sheet pile wall would be constructed to divert groundwater around/away from contaminated media. | Not Retained. Technically not feasible at this site because of constructability issues with the geologic conditions present. |
| | | Shallow Diversion | Shallow physical barriers (slurry walls, grout curtains, or sheet pile walls) would be constructed to isolate contaminated groundwater from shallow zone media such as sediment and surface water. | Technically feasible and potentially applicable for some portions on the site where groundwater is shallow like near ponds or drainages. |

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| General Response Action | Remedial Technology | Process Option | Description of Process Option | Technical Implementability/ Reason for Elimination |
|---|---|---|---|---|
| Containment (continued) | Physical Barriers (continued) | Compacted Soil/Clay Barrier | A layer of low permeability compacted fill would be installed to prevent migration of groundwater through contaminated solid media thereby reducing contaminant migration to groundwater. | Technically feasible and potentially applicable for some parts of the site with shallow groundwater like the pits. |
| | | Synthetic Barrier | Synthetic material would be installed around or under contaminated media to divert groundwater away from contaminated media and reduce contaminant migration to groundwater. | Technically feasible and potentially applicable for some parts of the site with shallow groundwater. Constructability concerns increase with depth and may limit potential use. |
| Removal | Passive Removal / Drainage | Gravity Drain | Groundwater in the pits would be limited to a specific elevation using a gravity drainage system and routed to a treatment plant for processing. | Technically feasible and potentially. Operation and maintenance could be problematic and cause performance problems. |
| | Active Extraction | Groundwater Extraction Wells | Groundwater would be removed using extraction wells and routed for treatment. | Technically feasible and potentially applicable. |
| | | Groundwater Extraction Trench | Groundwater would be collected within a trench and removed and routed for treatment. | Technically feasible and potentially applicable. |
| Treatment | Continue Operating Existing WTP [a] | Chemical Precipitation | Active water treatment continues using the existing water treatment plant without modification. Sludge generated during treatment would continue to be disposed off-site at the Ford Mill until closure or at a new disposal site. | Technically feasible and potentially applicable. |
| | Ex-Situ Physical/Chemical [a] | Aeration / Air Stripping | Injection of air into the contaminated water forming bubbles that transfer dissolved contaminants to the air phase for collection and/or treatment. | Technically feasible and potentially applicable. Proven method to remove radon from water. However, not effective for inorganics and radionuclides. |
| | | UV Oxidation | Uses ultraviolet radiation to destroy contaminants as the water flows into the treatment vessel. | Not Retained. Not effective for metals and radionuclides. |

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| General Response Action | Remedial Technology | Process Option | Description of Process Option | Technical Implementability/ Reason for Elimination |
|---|---|---|---|---|
| Treatment (continued) | Ex-Situ Physical/Chemical [a] (continued) | Chemical Oxidation | Oxidation chemically converts hazardous contaminants to non-hazardous or less toxic compounds that are more stable, less mobile, and/or inert. The oxidizing agents most commonly used are ozone, hydrogen peroxide, hypochlorites, chlorine, and chlorine dioxide. | Not Retained. Not effective for metals and radionuclides. |
| | | Ion Exchange | Contaminated water is passed through a resin bed where ions are exchanged between resin and water. Regeneration of resins results in concentrated brine that will need additional treatment and/or disposal. | Technically feasible and potentially applicable. Proven technology for removing metals and radionuclides from water. |
| | | Evaporation | This active or passive process evaporates the water to generate inorganic residuals that will require further treatment and/or disposal. | Not Retained. Not applicable for the large volume of water at this site. Not effective for radionuclides. |
| | *Precipitation* | Chemical Precipitation/ Coagulation/ Flocculation | Addition of chemicals such as lime or caustic soda to raise the pH and form insoluble inorganic species. Technology is currently being used at the site, but would likely be modified to improve performance and reduce sludge generation. Residual from the treatment is sludge. | Technically feasible and potentially applicable. Proven technology for metals and radionuclides that is currently being used on site. Current system may not be appropriate because of new site conditions. |
| | | Neutralization/ Precipitation | Adjustment of pH when soluble metal salts are converted to insoluble salts that will precipitate. Typically performed with lime or limestone, but the use of other alkalis is technically feasible. | Technically feasible and potentially applicable. Effective for metals and radionuclides. |
| | | High Density Sludge (HDS) | Chemical precipitation process that produces a high density sludge (increased solids content) thereby reducing the volume of sludge needing additional treatment and/or disposal. | Technically feasible and potentially applicable. Proven technology. |

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## FOR GROUNDWATER
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| General Response Action | Remedial Technology | Process Option | Description of Process Option | Technical Implementability/ Reason for Elimination |
|---|---|---|---|---|
| Treatment (continued) | Ex-Situ Physical/Chemical [a] *Precipitation* (continued) | GECO HDS Process | A variant to the conventional HDS process GECO uses a two step neutralization process producing a high density sludge. Recycled sludge is contacted with contaminated water in first reactor and lime slurry is added in second reactor. | Technically feasible and potentially applicable. Innovative and proprietary technology requiring treatability testing. |
| | | Silica Micro Encapsulation/ KEECO Process | A process similar to chemical precipitation. Chemical added to the contaminated media initiates a reaction process that involves precipitation and hydroxyl formation and an electrokinetic reaction. Silica components form a tight matrix around metals and produce more stable sludge that reduces leaching of contaminants. | Technically feasible and potentially applicable. Innovative and proprietary technology requiring treatability testing. |
| | | Dicalcium Silicate Process (Di-Cal) | Neutralization and precipitation process using $Ca_2SiO_4$ that produces fast filtering and more stable precipitates. | Technically feasible and potentially applicable. Innovative technology requiring treatability testing. |
| | | Self Assembled Monolayers on Mesoporous Supports (SAMMS) | Contaminated water contacts a self-assembled monolayer on mesoporous supports, a mesoporous ceramic technology. The specialized molecules latch onto heavy metal ions. | Technically feasible and potentially applicable. Innovative technology requiring treatability testing. |
| | *Separation* | Conventional Filtration | Filtration is the physical process of mechanical separation based on particle size whereby particles suspended in a fluid are separated by forcing the fluid through a porous medium. As fluid passes through the filter medium, the suspended particles are trapped on the surface of the medium and/or within the body of the medium. | Not Retained. Not effective for metals and radionuclides. |

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| General Response Action | Remedial Technology | Process Option | Description of Process Option | Technical Implementability/ Reason for Elimination |
|---|---|---|---|---|
| Treatment (continued) | Ex-Situ Physical/Chemical [a] *Separation* (continued) | Ultrafiltration/ Microfiltration | Ultrafiltration / microfiltration occurs when particles are separated by forcing fluid through a semipermeable membrane. Only the particles whose size are smaller than the openings of the membrane are allowed to flow through. | Technically feasible and potentially applicable. Would require treatability testing. |
| | | Multi Media Filter | Filtration of solid matter from water by passing the water through a vessel containing two or more porous mediums, such as sand, gravel, and anthracite. | Not Retained. Not effective for metals and radionuclides. |
| | | Reverse Osmosis | Contaminated water is passed through a semipermeable membrane at high pressure leaving a concentrated residual behind as membrane rejection. | Technically feasible and potentially applicable. Proven technology for metals and radionuclides. |
| | | Ceramic Microfiltration Technology | Liquid/solid separation process using advanced ceramic microfiltration membranes. Follows initial process of pH adjustment/chemical precipitation and allows for reduced consumption of chemicals. | Technically feasible and potentially applicable. Proven effective for metals. |
| | | Liquid Emulsion Membranes | Technology that uses liquid emulsion membranes to selectively extract metals from solutions. Process consists of iron precipitation with hydrogen peroxide, lime addition to raise pH, treatment of supernatant through a filter, extraction, and stripping operations. | Technically feasible and potentially applicable. Innovative technology requiring treatability testing. |
| | | Electrodialysis | Ionic species are removed from water through a membrane separation process. | Technically feasible and potentially applicable. Would require treatability testing. |

# GENERAL RESPONSE ACTIONS FOR GROUNDWATER

## With Initial Screening of Technologies and Process Options

| General Response Action | Remedial Technology | Process Option | Description of Process Option | Technical Implementability/ Reason for Elimination |
|---|---|---|---|---|
| Treatment (continued) | Ex-Situ Physical/Chemical [a] *Separation* (continued) | Electrokinetic Separation | Separation of contaminants using a direct current electric field by causing water and contaminants to flow between electrodes. The flow causes migration and concentration of COCs for their removal. | Not Retained. Not effective for radionuclides. |
| | *Adsorption/ Absorption* | Carbon Adsorption | Contaminated water is passed through a column of granular activated carbon and contaminants are adsorbed to the media. Once spent the carbon can be regenerated. | Not Retained. Technically feasible for removal of radionuclides and some metals, but has limited capacity for inorganics. Not applicable for the high volume of water at the site. |
| | | Synthetic Resins | Special resins would be used, which are designed to adsorb COCs. Once spent the resins can be regenerated using acids, bases, or solvents. | Not Retained. Not effective for metals and radionuclides. |
| | | Forage Sponge | An open-celled cellulose sponge incorporating an amine-containing chelating polymer that selectively absorbs dissolved heavy metals. | Technically feasible and potentially applicable. Innovative technology requiring treatability testing. |
| | In-Situ Physical/ Chemical | Passive Reactive Barrier Wall | Contaminated water would be remediated through in-situ chemical reactions with chemically or biologically active materials contained in an installed subsurface wall. Zero valent iron is commonly used as a reactive medium. Other media may also be used, such as limestone or apatite. | Technically feasible and potentially applicable. Innovative technology requiring treatability testing. |

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| General Response Action | Remedial Technology | Process Option | Description of Process Option | Technical Implementability/ Reason for Elimination |
|---|---|---|---|---|
| Treatment (continued) | Biological Treatment | Aerobic Treatment | Microorganisms are used to remove contaminants from water in an oxygen rich environment. | Not Retained. Not effective for metals and radionuclides. |
| | | Anaerobic Bioreactors (SRB) | Bacterial reduction of sulfate and iron and precipitation of metals sulfides. Biological reactions are utilized for chemical reduction of the wastewater contaminants in an oxygen free environment. | Technically feasible and potentially applicable. Would require treatability testing. |
| | | Constructed Wetlands | Wetlands would be used to create aerobic and anaerobic environments for the removal of dissolved metals. Natural geochemical and biological processes accumulate and remove metals. Sulfate-reducing microorganisms in the anaerobic zone of substrate material cause a breakdown of sulfate and the subsequent precipitation of sulfides. | Technically feasible and potentially applicable. Would require treatability testing. |
| | | Bacterial Reduction | Introduction of bacteria to promote the immobilization of metals by creating reducing conditions. | Technically feasible and potentially applicable. Innovative technology requiring treatability testing. |
| | | Biosulphide Process | An integrated two-stage chemical/ biological process which concurrently recovers metal and sulfide-based coproducts. Consists of sulfate-reducing bacteria process and precipitation process. | Technically feasible and potentially applicable. Innovative technology requiring treatability testing. |
| | | Phytoremediation | Direct use of plants and their associated rhizospheric microorganisms to remove, degrade or contain chemical contaminants in soils and water. | Technically feasible and potentially applicable for areas with shallow groundwater, such as near drainages and ponds. The technology is not effective beyond the depth of the plant roots. |

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| General Response Action | Remedial Technology | Process Option | Description of Process Option | Technical Implementability/ Reason for Elimination |
|---|---|---|---|---|
| Disposal of Water | On-Site Disposal of Treated Water | Surface Water Discharge | Discharge of treated water to existing drainage or pond. Water would travel to Lake Roosevelt via Blue Creek. | Technically feasible and potentially applicable. Discharge from the existing Water Treatment Plant currently disposed of in this manner. |
| | | Aquifer Recharge | Percolation of treated water into aquifer through shallow and/or deep injection wells, infiltration galleries, or surface irrigation. | Technically feasible and potentially applicable. |
| | Off-Site Disposal | POTW | Groundwater would be extracted and pumped to an existing publicly owned treatment works plant. | Not Retained. There is no POTW located near site. |
| | | TSD Facility | Groundwater would be extracted and pumped to a tanker truck, hauled to an offsite TSD facility for treatment and disposal. | Not Retained. Not feasible for the large volume of water at this site with no TSD Facility located near site. |

GENERAL RESPONSE ACTIONS
FOR GROUNDWATER
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**Denotes remedial technology process option that will not be carried forward for additional evaluation.**

[a] Residuals produced during ex-situ physical/chemical treatment of water will likely follow one of the off-site disposal process options presented on Table 2-1. Disposal of residuals will depend on the various treatment alternatives selected. In addition, the residuals may go through additional treatment or waste minimization process prior to final disposal.

**Notes:** 1) Multiple response actions and remedial technologies will be combined to develop alternatives for groundwater.

2) Process options retained for additional evaluation may not be applicable to all locations of the site or material types present at the site.

3) Based on the NCP, consolidation/containment remedial technologies are preferred for contaminated material with large volumes and low concentration levels. Smaller volumes of material with higher concentrations are more suited for treatment.

4) Remedial technologies requiring treatability testing could be performed during the remedial design phase.